Assessment of Electrical Resistivity Anomalies Caused by Fresh Water Discharge Across the Continental Shelf: Seeps off North Carolina

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LONG-TERM GOALS

To determine the impact that fresh water discharge across the continental shelf has on the electrical resistivity structure of bottom sediments and, by so doing, to use electrical measurements to constrain the regional hydrology and the exchange of continentally derived groundwater with the ocean. The strength and spatial distribution of resistivity anomalies caused by fresh water will be used to assess the likelihood of false target identification in mine counter measures, and the degree to which bottom conditions might be misclassified. The discharge of fresh water through permeable aquifer units may also be an important factor in slope failure.

OBJECTIVES

- Measuring and quantifying anomalous resistivity structures in a region of continental shelf known to be discharging of fresh water into the ocean.

APPROACH

The role of groundwater discharge on margin processes is one that is only beginning to be understood. Estimates of the amount of fresh water discharged from the continent through bedrock and into the ocean vary widely, and while some have suggested it is of a similar magnitude to riverine discharge, this remains a controversial issue. Most work to quantify the distribution and fluxes of fresh water across continental margins has been geochemical: there are few geophysical techniques that are sensitive to the presence of fresh pore water. However, electromagnetic techniques might respond to regions containing fresh water, as the electrical resistivity of the bulk sediment would be increased if the freshening were pervasive. We have seen off northern California regions of several hundred square meters which have extremely high electrical resistivities (for example, whereas normal sediments have resistivities of around 1 ohm-m near the seafloor, we saw values as high as several hundred ohm-m within 1-2m of the seafloor). Although we do not know at this time whether fresh water is responsible for these resistivities, we have carried out modeling based on observations of fresh water beneath the seafloor to show that this explanation is plausible.

We plan to take the Canadian towed EM system that we have used in two successful ONR funded cruises, to a region of known and quantified fresh water discharge in an attempt to quantify the extent of pore water freshening in the near surface sediments. The system, which is towed along bottom provides more or less continuous resistivity-depth profiles along a tow line and so is ideal for providing spatial maps of resistivity variation, whether they are caused by changes in facies conditions or by the influence of groundwater. This is in contrast to other EM techniques which place a remote

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receiver on the seafloor and transmit to it with a towed source: local heterogeneity in resistivity structure at the length scale we are interested in, will act as a source of noise in this kind of survey and will be hard to resolve.

The EM system we use measures the electrical resistivity of the seafloor which we convert to apparent porosity using empirical relationships and the assumption that the pore water has the same salinity as the near-bottom seawater. If this assumption is not valid, because the pore water is in fact fresher than seawater, then we will underpredict the porosity. In a survey off California, we predicted porosities of less than 15% in a few places close to shore. We know that these locations are immediately north of a shallow anticline system, and so one explanation for our observations has been that the pore water is fresh and is groundwater that is being channeled to the seafloor through faults associated with the anticline system. In the Californian case, we have not been able to prove this model. In order to unequivocally determine that any observed anomalies in this survey are caused by fresh water and to place our measurements in the context of regional hydrology, we will sample fluids and take CTD measurements above areas of anomalous resistivity as well as analysing samples from existing wells onshore, which tap the source of the discharge.

WORK COMPLETED

A series of preliminary models have been run using salinity profiles obtained at a variety of locations on the U.S. East Coast to predict the impact of fresh pore water on electrical resistivity. The observed salinities have been combined with realistic sedimentary porosities to calculate resistivity depth profiles. The responses of these profiles to excitation with the towed EM source we plan to use in a survey next year were calculated. The responses show a significant effect on predicted apparent porosities that would be inferred with the EM system. The salinity profiles are reassurance against the argument that porewaters will never be sufficiently fresh to measure with electrical methods due to mixing with seawater. While such mixing does occur in certain hydrologies, and indeed is an important component of chemical transfer to the seafloor, it does not always occur and fresh water can reach to within a few meters of the seafloor, and can even discharge directly onto the seafloor at discrete locations.

RESULTS

The modeling results are encouraging inasmuch as they predict marked anomalies above fresh water seeps of realistic salinity. We have discussed with Dr. W. Moore and with Dr. S. Riggs potential locations for our survey, which is now to be run next April. Our primary site is in Onslow Bay, off north Carolina, where Dr. Riggs' group have observed active discharge of fresh water. Another site which we discussed with Dr. Moore, further south off South Carolina, does show evidence for the impact of fresh water on bottom water chemistry, but through a process of exchange and mixing in the subsurface rather than the direct discharge of fresh water.

IMPACT

The loss of continental groundwater to the oceans is a potentially important area of research both from an oceanographic and from a societal viewpoint. Thus, the use of EM surveys to identify groundwater discharge will be of fundamental importance, not only to the Navy in its mine counter measures efforts, but also to a large geological and hydrological community seeking to understand the exchange of groundwater with the oceans. To date, there is a lack of geophysical constraint on this process, since few methods have direct sensitivity to the presence of fresh pore water. If our survey is successful, it will open up a new avenue of exploration.

RELATED PROJECTS

I have been funded by NSF to develop a towed EM capability at WHOI, and work is underway on the construction of a similar instrument to that operated by the geolgical survey of Canada.

PUBLICATIONS

Evans, R.L., L.K. Law, B. St. Louis, S. Cheesman and K. Sananikone, The shallow porosity structure of the Eel shelf, northern California: results of a towed electromagnetic survey. Marine Geology, 154, 1999.

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